Volume 20 July, 1934 *Number 7*

Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

Prediction of Lubricant Performance

Paper Mills Calender Stacks

PUBLISHED BY
THE TEXAS COMPANY
TEXACO PETROLEUM PRODUCTS

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Published by

The Texas Company, 135 East 42nd Street, New York City

Vol. XX July, 1934 No. 7

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Prediction of Lubricant Performance

Relation of Specifications to Operating Requirements

THE necessity for laboratory anticipation of operating conditions has presented a distinct need for more study in regard to developing the extent to which certain laboratory tests will predict the results to be obtained from a lubricant or petroleum product in actual service. A variety of new tests has been developed within recent years. Some are distinctive in that their purpose is to foretell the degree of wear which may be expected under certain operating conditions. Others simply show change in physical or chemical characteristics of the lubricant.

The difficulty lies in anticipating just what these operating conditions may be, and in successfully duplicating them in the laboratory. This is particularly true where lubricants are involved, for in nearly every instance there are certain conditions of operation which must be thoroughly understood, especially with respect to their influence upon the physical characteristics and performance of any petroleum lubricant, before decision is made as to the particular laboratory tests which will indicate the extent to which such products would function satisfactorily.

In appreciation of these facts, lubrication technicians have devoted much time to the development of laboratory testing devices which will not only enable study of the performance of lubricants under accurately controlled conditions, simulating operating requirements as nearly as possible, but which will also eliminate the time element which is always so prominent a factor in the carrying out of any actual operating test. The purpose of any such method of laboratory determination of lubricating ability is to ascertain in a short time what can be expected of a lubricant over a long period of service.

The Navy Work Factor machine and the apparatus devised by certain industrial laboratories for indicating the ability of various types of lubricants to function under severe operating conditions have been noteworthy in this regard.

Of still more recent development has been the activity in the interest of predicting the performance of greases under long time service in ball bearings. Manufacturers of bearings as well as the laboratories of certain prominent oil companies have been identified in this particular research, to the end that practical equipment has been developed for determination of starting and running torque, durability, and change in the characteristics of greases under various speed and temperature conditions.

From a fuel point of view, the practicability of present day methods of laboratory distillation and the value of the distillation curve in giving a good indication of what can be expected from a gasoline under cold starting conditions, acceleration, and steady driving are accepted by research authorities throughout the petroleum industry.

LUBRICATING VALUE

The accepted physical tests which have been worked out as being most pertinent in connection with lubricants include:

Viscosity, as an indication of relative fluidity at any particular temperature.

The carbon residue test, as a criterion of breakdown and formation of potential non-lubricating deposits.

The pour test, as a means of determining the ability of an oil to flow under low temperatures, and

Consistency, or penetration, in connection with pressure-resisting ability of a grease.

Check results are, of course, most important in the manipulation of any type of laboratory equipment, for unless it is practicable to duplicate such results, the value of the test is questionable.

With this purpose in mind, research authorities, in the perfection of test procedures, should make every endeavor to obtain a thorough understanding of service conditions; their tests, in turn, being capable of practicable, accurate checking.

The opinions of J. G. O'Neill,* of the U. S. Naval Engineering Experimental Station, Annapolis, Maryland, relative to the Practical Interpretation of Lubricant Specifications, are of particular interest. He states:

"Most engineering materials are well specified and there is little, if any, doubt as regards their suitability for their designed uses. Their properties, safety factors and limitations are well recognized. But the situation as regards lubricating oils is quite different. It is true that their properties are determined, but what do these properties mean? What are their safety factors and what are their limitations? The lack of definite information in these respects has been the stumbling block to the preparation of specifications for lubricants. By the absence of specifications, the refiner is called upon not only to supply satisfactory lubricants, but to guarantee satisfactory service under conditions over which he has no control.

"It is well to bear in mind that successful lubrication is dependent on a great many factors other than the quality of the lubricant. It is ridiculous to think that improper application of the lubricant, poor conditions of the machinery and unskilled operation may be overcome by the quality of the lubricant. It must be remembered that to obtain the ideal in lubrication is almost an impossibility, since the mechanical condition of machinery is never perfect and many factors difficult to control enter into the problem.

"The first requisite of successful lubrication is that a film of lubricant exist between rubbing surfaces and prevent metallic contact. The

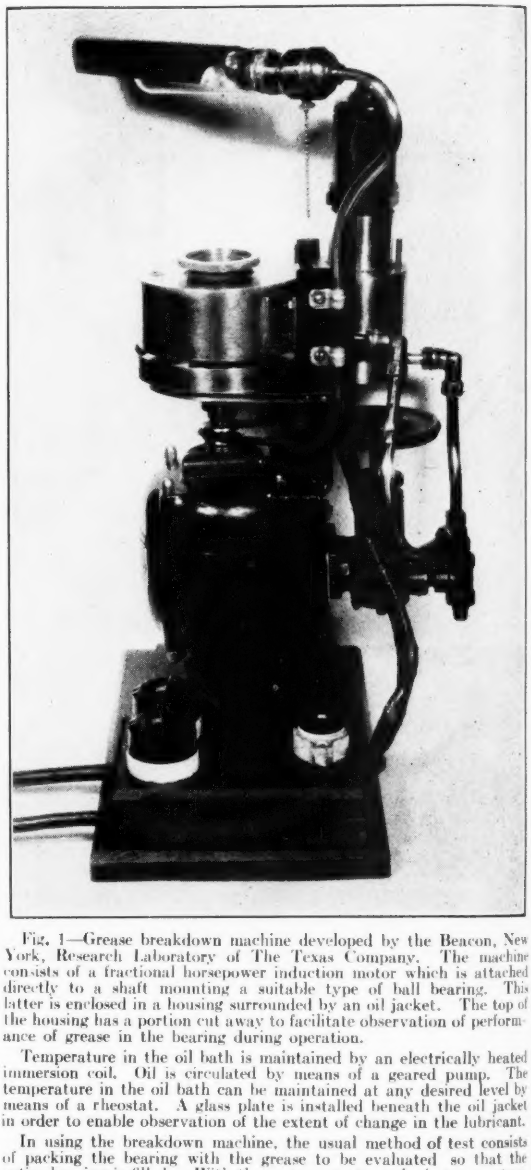


Fig. 1—Grease breakdown machine developed by the Beacon, New York, Research Laboratory of The Texas Company. The machine consists of a fractional horsepower induction motor which is attached directly to a shaft mounting a suitable type of ball bearing. This latter is enclosed in a housing surrounded by an oil jacket. The top of the housing has a portion cut away to facilitate observation of performance of grease in the bearing during operation.

Temperature in the oil bath is maintained by an electrically heated immersion coil. Oil is circulated by means of a geared pump. The temperature in the oil bath can be maintained at any desired level by means of a rheostat. A glass plate is installed beneath the oil jacket in order to enable observation of the extent of change in the lubricant.

In using the breakdown machine, the usual method of test consists of packing the bearing with the grease to be evaluated so that the entire housing is filled. With the system at atmospheric temperature, operation is started and allowed to proceed for three minutes, during which time any tendency toward change in consistency or texture is observed as well as the nature of the lubrication provided, i.e., whether or not the grease folds over the bearing, channels, slings away from the bearing or tends to build up.

After this observation, heat is turned on and the temperature is allowed to rise until the grease fails to lubricate or the temperature reaches a maximum of 300°F. Beginning at 100°F., observations are recorded for every 25° rise or at any extraordinary development such as change in texture, expansion in volume and entrainment of air, channeling, leakage, melting and consequent thinning, separation, discoloration or vaporization.

After the test is completed, the bearing is removed, cooled, and the amount of grease which may have leaked past the seal is noted and taken as an indication of consumption. Upon complete cooling, the remaining grease is examined for any alteration in consistency or texture as compared with the original product.

* Penn State College. Tech. Bulletin No. 18, pp. 5-8. Proceedings of the Seventh Oil Power Conference. Devoted to Lubrication Engineering, Penn State College, May 25-26, 1933, with Petroleum Div. Am. Soc. Mech. Eng.

ability to form a lubricating film is not confined to oils or fats, for many liquids, even gases, have this property and it is simply a matter of proper application of the lubricant to obtain such a film. In general, where extreme pressures are not encountered, the formation of a lubricating film is simply a matter of mechanics and has very little to do with the quality of the lubricant. Successful film lubrication has been obtained with light transil oils with a shaft speed of 2000 linear feet per minute, 150 pounds per square inch bearing pressure and at a bearing temperature of 150 degrees Fahrenheit. It is obvious, therefore, that if a lubricating film may be obtained from oils of too low viscosity to be classed as lubricants, that the governing characteristics of film lubrication are design of bearings, application of the lubricant, and sufficient supply of the lubricant.

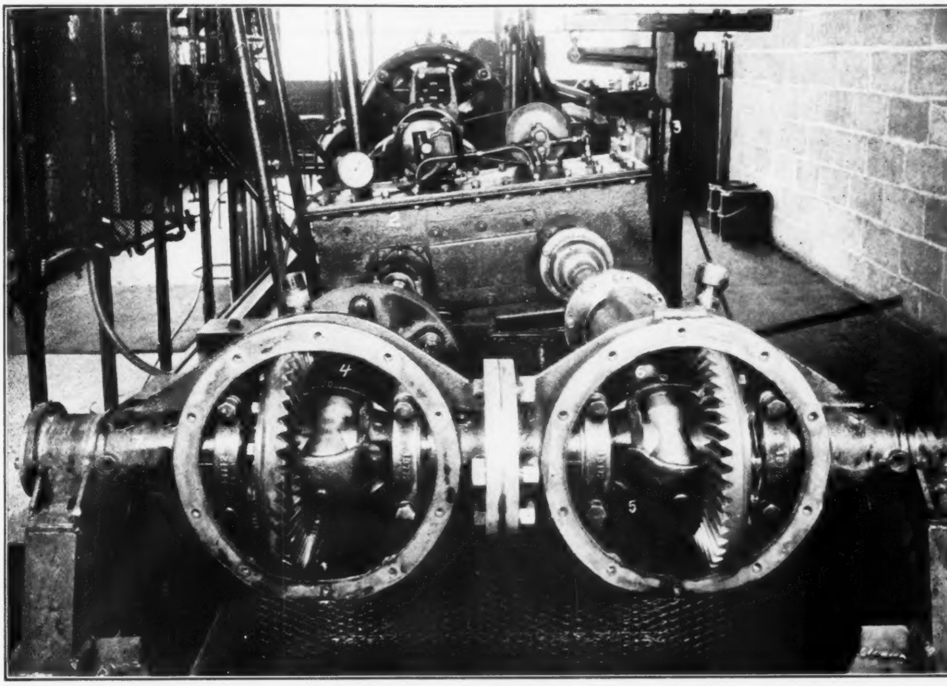


Fig. 2—Hypoid gear test set up as installed at the Beacon, New York, Research Laboratory of The Texas Company. Explanation of figures shown is given below:
1. Cradle mounted dynamometer used to drive the system and also to measure the torque input to the system.
2. Transmission box containing four herringbone gears, one of which is on each of the two shafts, the other two gears being idlers between the two shafts.
3 Platform scale, used to measure torque load applied to the hypoid gears. The transmission is hung, or pivoted about the shaft immediately under the number 2. Raising the box about this shaft applies a load to the system, which is measured by the reaction of the box against the platform scale.
4. Differential carrier—from which differential gears have been removed and replaced with a shaft which connects the two ring gears.
5. Same as No. 4.
6. Pinion gear.
7. Axle housing.

"Lubricating oils, no matter from what crude they are made, generate the same amount of friction if they are of the same viscosity at a definite operating temperature. The refiner of lubricating oils cannot by any method of refinement, change this basic quality of lubricating oil and, with the exception of lubricating oil used under extreme pressures where rupture of the lubricating film may occur, there is no material which may be added to lubricating oil which will reduce its frictional properties unless it also reduces its viscosity. Of late years, there has been a noticeable falling off of 'quack' remedies for reducing the friction of lubricating oil, but there still exist a number of such remedies, many of them containing materials which are actually abrasive or liable to cause serious damage by settling out and plugging oil ways. There is only one sensible way of reducing the friction of machinery and that is by development of the art of making machines, so that they may be operated on lower viscosity lubricating oils with less loss of frictional heat and with greater efficiency. The use of the better refined, lower viscosity lubricating oils for motive equipment will be a salient advance in modern engineering.

"One of the fundamental factors for successful lubrication lies in the skill and reputation

of the machine builder; his ability to produce a machine free from excessive vibrations, properly aligned and carefully adjusted. Careless workmanship cannot be remedied by the use of any lubricating oil.

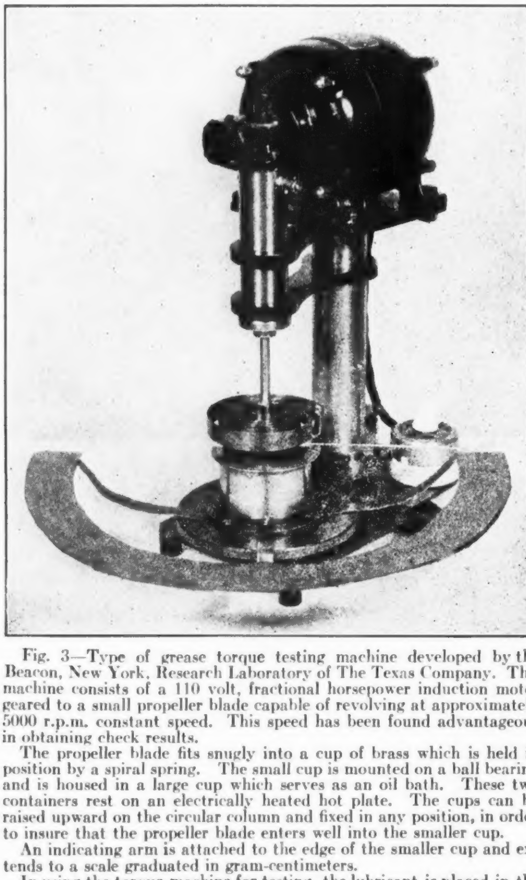


Fig. 3—Type of grease torque testing machine developed by the Beacon, New York, Research Laboratory of The Texas Company. This machine consists of a 110 volt, fractional horsepower induction motor geared to a small propeller blade capable of revolving at approximately 5000 r.p.m. constant speed. This speed has been found advantageous in obtaining check results.

The propeller blade fits snugly into a cup of brass which is held in position by a spiral spring. The small cup is mounted on a ball bearing and is housed in a large cup which serves as an oil bath. These two containers rest on an electrically heated hot plate. The cups can be raised upward on the circular column and fixed in any position, in order to insure that the propeller blade enters well into the smaller cup.

An indicating arm is attached to the edge of the smaller cup and extends to a scale graduated in gram-centimeters.

In using the torque machine for testing, the lubricant is placed in the smaller cup almost to the top. The cup is then raised a constant height so that the propeller blade is always the same distance from the cup bottom. The temperature is taken before starting, after which the motor and a stop watch are started simultaneously. The farthest upward point which the indicator arm reaches on the scale is recorded as the starting torque. The position of the arm is also noted at ½, 1, 2, 3, 4, 5 and one minute intervals up to 20 minutes. The point on the scale to which the arm finally becomes fairly constant is called the running torque.

In addition to this atmospheric test, standard practice also includes making the same 20 minute run at 150 and 200°F.

"The mechanical condition of machinery is intimately related to its operation and the perfect functioning of machinery is by no means common. While the supervision of machinery has become a common, every-day occupation, intelligent operation is an art and in the present day demands not only a knowledge of machinery, but also a knowledge of all the materials which make operation possible."

"It has been observed that a good operator may make a creditable showing on a comparatively poor oil, while a poor operator may ruin the best of oils. The discrepancies of engine condition and operation are innumerable. Dilution of the lubricating oil from the fuel, contamination of lubricating oil systems and 'sludging' of the lubricating oil are, in a great majority of cases, but little related to the quality of the oil. It is for this reason that great care should be taken in subjecting oils to service tests. Unless such care is taken there is grave danger of arriving at false conclusions.

"By the use of lubricating oil, there is substituted for the friction of rubbing metallic surfaces, the friction of moving molecules of oil. In a perfectly lubricated bearing there is formed a film of oil between the bearing metal and the rotating shaft; the friction generated is from the molecules of oil as they slide over each other.

"The main factors that control the choice of a lubricant are: the bearing pressure, the rubbing speed, the temperature of operation and the bearing clearances. With increase in bearing pressures, the viscosity of the oil to be used should be increased, since the higher viscosity oils give a thicker, more adhesive film which is more difficult to squeeze from between the shaft and bearing. The friction is greater when using a higher viscosity lubricating oil than when using a lower viscosity oil; this is apparent by higher running temperatures. Machinery which has large clearances, or which is subject to vibration, requires the use of the very viscous oils in order to maintain a satisfactory oil pressure or to act as a cushioning medium to prevent rupture of the oil film. It is customary in marine work to use a rather more viscous oil than is absolutely necessary since it is advisable to limit the number of grades of oil, one grade performing several different duties.

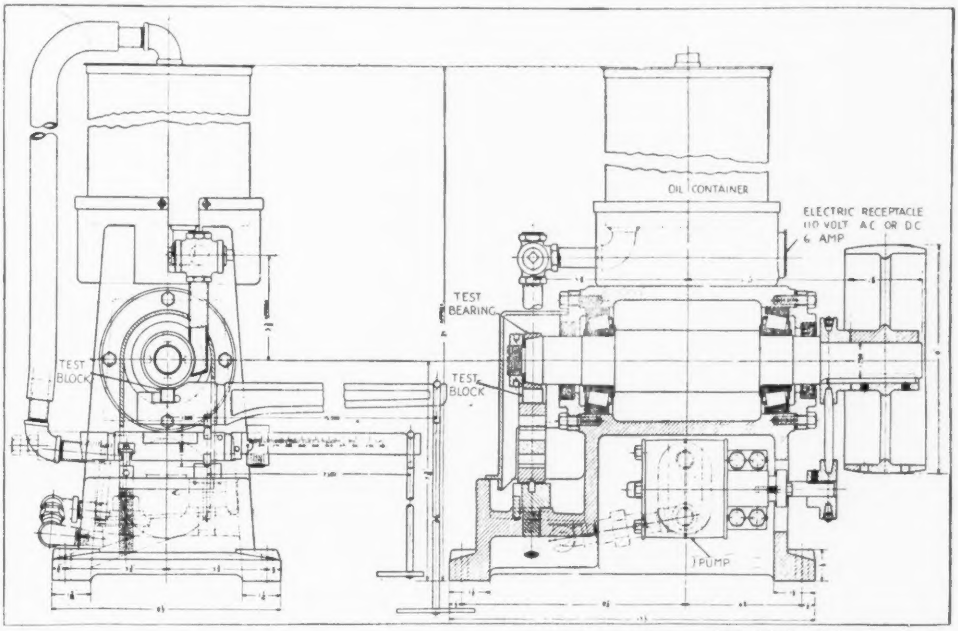
"Machinery operated at high speeds should use oils as low as possible in viscosity, since higher rubbing speeds greatly increase friction.

"All lubricating oils decrease in viscosity with rise in temperature and in order that the oil may have sufficient viscosity to form a proper lubricating film it is necessary to take into account any high operating temperatures encountered. On the other hand, when operating at low temperatures it is necessary to use an oil which is sufficiently fluid to pump or splash to the parts to be lubricated; otherwise a dry cylinder or bearing may result.

"During cold weather it is almost impossible to prevent dilution of the lubricating oil of motor car engines from the fuel when using the ordinary motor gasoline; the volatility of the gasoline being too poor to form an explosive mixture, part of it condenses in the cylinders and flows into the lubricating oil in the crankcase. This condition necessitates the use of a much higher viscosity oil than should otherwise be necessary. Worn pistons, cylinders and

piston rings also require the use of higher viscosity oils in order to form a seal between pistons and cylinders.

"In lubricating rubbing surfaces which are in a wet condition, it is necessary to compound may be made of different viscosities so that it may meet various mechanical conditions. It is this flexibility, combined with its great stability, which makes mineral lubricating oil of such great value for lubrication.



Courtesy of The Timken Roller Bearing Co.

Fig. 4—Sectional view of the Timken Lubricant Testor showing general construction and overall dimensions.

mineral oil with tallow or lard oil in order to reduce the surface tension of the lubricant, spread on the surfaces and provide lubrication.

"It is sometimes necessary to increase the penetrating properties of mineral oil for use in bearings or cylinders, which are too tightly fitted; this is accomplished by compounding the mineral oil with a small amount of lard oil.

"Marine reciprocating engines lubricated by wick feed require the use of a mineral oil, thickened by blown rapeseed oil in order to give it well sustained viscosity at high intermittent pressures and to provide lubrication in case a stream of salt water is played on the journal. The oil readily mixes with the water and forms a thick, adhesive emulsion.

"It is apparent that the problems of lubrication are very complicated and that a restricted view of any one phase of these problems does not offer a complete solution. While the quality of the lubricant is of great importance, it is, after all, only one of the components of successful lubrication.

"Any liquid which will readily form a lubricating film, give low frictional losses and be resistant to physical and chemical changes, will serve as a lubricant. The most abundant liquid possessing all three qualities to a marked extent is mineral lubricating oil. Moreover, it

"Every mineral lubricating oil is made up of a great number of organic compounds of slightly varying properties. The theory is often advanced that in order to be a good lubricant an oil must possess a certain amount of some intangible substance which is the essence of lubrication, while as a matter of fact all of the organic compounds in a lubricating oil are lubricants.

"The study of any lubrication problem requires exact knowledge of the properties of the lubricant employed. Confidence in the ability of the lubricant to meet normal operating conditions is an important step in the solution of any problem of lubrication."

TESTING FOR SERVICE PERFORMANCE

In view of the continued interest in improving upon the methods of laboratory test whereby prediction of lubricant performance under simulated operating conditions can be made, it is deemed advisable to repeat our discussion of certain of the outstanding methods of test which was presented in the July-August, 1931 issue of magazine LUBRICATION. Illustration of the improved types of machines which are today being used should be of particular interest:

Testing for service performance, in addition

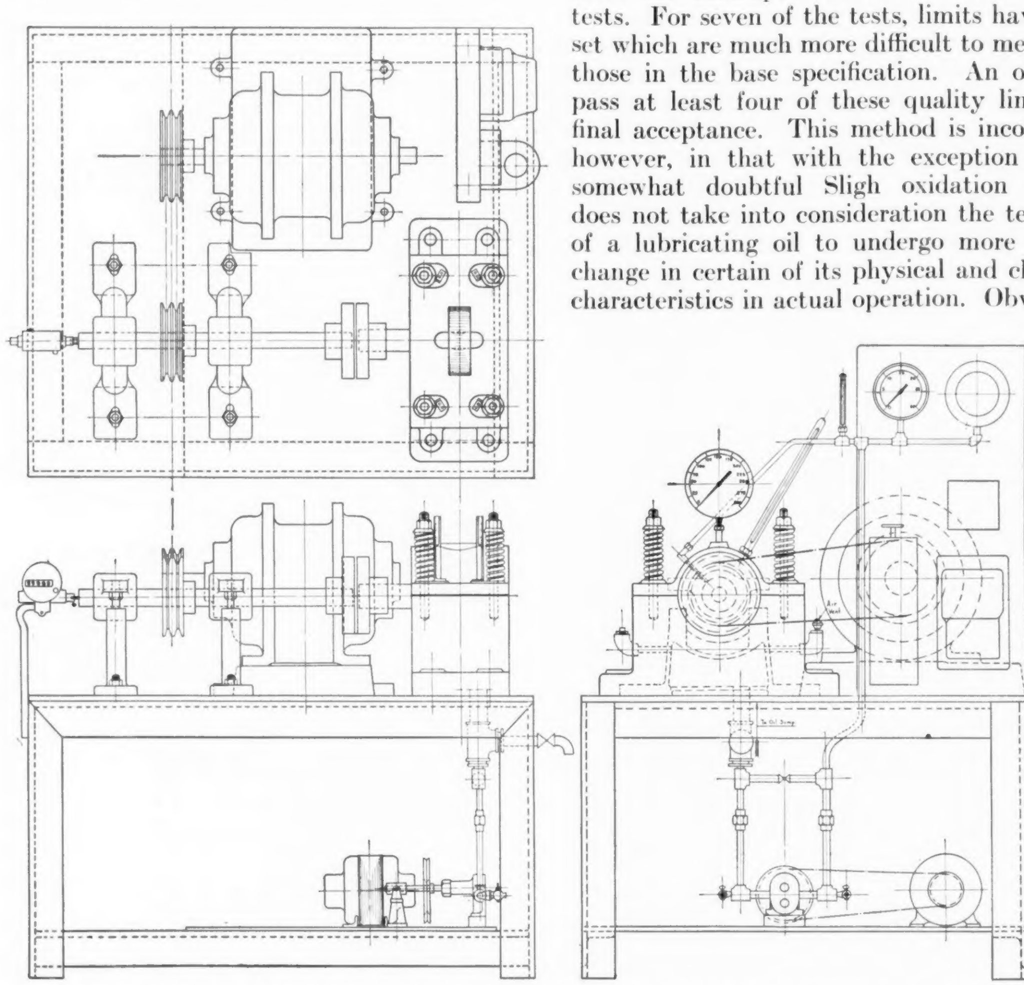


Fig. 5—The Work Factor Machine, as developed by the U. S. Navy, consists primarily of a journal in a split bearing, $3\frac{53}{64}$ inches in diameter and $6\frac{1}{8}$ inches long, on which load is placed by four coil springs. It is driven by an electric motor at 2000 r.p.m. The normal load on the bearing is 150 pounds per square inch. Under these conditions the apparatus is run for 100 hours, after which tests are made on the oil to show the changes resulting from the high temperature occurring in the oil film.

to being of vital interest to the manufacturers of lubricants, has also been carefully studied by machinery builders and certain government agencies such as the United States Naval Engineering Experiment Station and the Bureau of Standards. Some of the equipment developed gives qualitative indication of lubricating value, while it is claimed for others that they make possible direct measurement of this value in terms of wear or torque. The government methods as applied to oils give weighted values to certain physical characteristics and changes in same, after subjecting an oil to intensive accelerated service in the laboratory testing machine.

The Federal Specification Board, representing various branches of the U. S. Government, in turn, has recently worked out a system for determining quality in lubricating oils based on the value of such physical characteristics as the flash point, pour point, color, carbon residue, the Sligh oxidation test, the neutralization test, the viscosity slope, and corrosion.

For tentative acceptance, an oil must first meet the base specification for each of these tests. For seven of the tests, limits have been set which are much more difficult to meet than those in the base specification. An oil must pass at least four of these quality limits for final acceptance. This method is incomplete, however, in that with the exception of the somewhat doubtful Sligh oxidation test it does not take into consideration the tendency of a lubricating oil to undergo more or less change in certain of its physical and chemical characteristics in actual operation. Obviously, such change is bound to occur, and any method of test to be of much value should indicate the extent of change under as nearly actual operating conditions as possible.

Grease Performance Dependent On Resistance to Breakdown

For this reason, lubricating value of greases has been studied primarily with the view of determining the durability or resistance to breakdown. To accomplish this it has been necessary to design laboratory experimental apparatus which will carry a typical bearing installation and which can be so subjected to variation in speed, temperature and load as to

render practicable the simulation of virtually any phase of actual operation. Certain manufacturers of anti-friction bearings have devoted much study to this phase of the problem, until today it is safe to say that testing of greases for service performance has become one of the outstanding advances in this move towards prediction of lubricating value.

In such a study of greases, it is perfectly feasible to run a sample under any set of predetermined operating conditions the bearing and its lubricant being at least partly visible during the entire run. (See Fig. No. 1.) This is an especially valuable feature, inasmuch as it permits of constant observation of the lubricant. As a general rule, appreciable thickening or separation of the average grease can be readily noted. Thickening, separation or oxidation may all be indicative of breakdown in a grease, and reduction in lubricating value. As a result, any testing device should permit of their discovery as soon as possible.

Subjection of a grease to such a test, under carefully controlled temperatures and speeds, will indicate the range of these latter over which the product may be expected to retain its homogeneity and lubricating value. Actual study of change of physical characteristics of a grease can also be made in connection with the use of such a testing machine.

On the other hand, no method of evaluating the extent of such changes has as yet been devised for use with greases. It is reasonable to presume, however, that with perfection and more extensive adoption of endurance methods of testing for actual lubricating value of greases, factors will be developed whereby one grease can be readily contrasted with another, by virtue of the rate of change in its physical and perhaps chemical characteristics. Studies involving accelerated oxidation have received careful consideration in this regard.

Gear and Heavy Duty Bearing Lubrication Requirements

To determine more specifically the characteristics which gear lubricants and those designed for heavy duty bearing service should possess in order to meet the intensive tooth loads and high rubbing speeds involved in modern automotive gear installations and steel rolling mill service, the Timken Roller Bearing Company, in turn, has recently conducted some very interesting tests on a distinctive type of test machine, as shown in Figure 4. The General Motors Corporation, the U. S. Bureau of Standards, and others have also carried on work in a more or less similar manner.

These tests were instigated by the lack of definite information regarding the ability of lubricants used in transmissions and rear axles to prevent scoring or scuffing under the higher tooth loads and rubbing speeds which have come into use, abrasion being studied with reference to anti-friction bearings of the type normally used in such installations. The data developed is of value in contrasting the lubricating ability of straight mineral gear lubricants with those containing compounds, such as lead soap, sulphur, chlorine or other materials. Results seem to indicate, however, that a compromise between tooth scuffing and bearing wear must be allowed for, especially in the design of gears, with more consideration of the lubricating qualities of the average lubricant.

To date, however, considerable difficulty has been experienced in obtaining check results from certain of the machines designed for this work. At the request of the Society of Automotive Engineers, Lubricants Division, the U. S. Bureau of Standards developed a machine using the salient points of existing machines. Their specific purpose was to obtain check results and correlate them with the results to be expected in actual service performance from the lubricants under test.

All these machines are strictly mechanical in their ability to predict the film strength of an oil or grease. They do not predict the long range chemical stability or the tendency towards oxidation in actual service. It has been found, however, particularly in connection with hypoid gears actually run in a laboratory installation under controlled conditions, that the tendency of certain types of lubricants to break down chemically and become oxidized or thickened in service, can be determined. It is felt, therefore, with the type of testing equipment available today, that it is absolutely essential to run actual service tests under controlled conditions, inasmuch as the chemical stability of a lubricant is equally, or even more important than resistance to film rupture.

The Navy Work Factor Method

It is interesting to note how the tendency for a lubricating oil to change in physical and chemical characteristics has been taken into consideration in the development of the Navy method for determining lubricating ability. With this as a basis, the laboratory procedure, as worked out at the United States Naval Experiment Station at Annapolis, is of particular interest.

For years it has been realized that physical changes, notably with respect to viscosity, the percent of carbon residue, acidity and sludge formation, have been indicative of what might be termed decrease in lubricating value. Until lately they have been considered individually, even though it was fully appreciated that they

did not afford a practical means of indicating actual lubricating value, or variations in this latter.

Development of the Navy Work Factor machine has led to study of their composite relations. As a result, we have a practicable means of subjecting lubricating oils to an accelerated service or endurance test, wherein operating conditions can be maintained and controlled, dependent upon the service for which any particular oil is intended. According to James G. O'Neill* this affords . . . "a convenient means for study of various problems of lubrication such as: the effect on the oil of different bearing metals, the depreciation of the oil with excessive or scant flow of oil to the bearings, the effect of excessive vibration of the journals and, possibly, the effect of different gases on lubricating oil during operation. It is believed that the solution of these problems will be greatly aided by means of the endurance test and the work factor."

Calculation of the Navy Work Factor

The work factor itself is based upon the increase in viscosity, neutralization number, and percent of carbon residue of a lubricating oil when subjected to service in the above mentioned machine. These numerical differences are incorporated into formulas to arrive at so-called work values for the respective tests. The average of these work values is termed the work factor of the oil under test. The respective formulas are noted below:

Viscosity Work Value (for oils below 75 seconds Saybolt at 210°F.)

$$\text{Work Value} = 1.00 - \left(\frac{\text{final viscosity} - \text{initial viscosity}}{\text{initial viscosity}} \times 5\right)$$

Viscosity Work Value (for oils above this viscosity)

$$\text{Work Value} = 1.00 - \left(\frac{\text{final viscosity} - \text{initial viscosity}}{\text{initial viscosity}} \times 4\right)$$

The neutralization number and carbon residue work values are each determined by the following formula:

$$\text{Work Value} = \frac{\text{final rejection point} - \text{final content or content of used oil}}{\text{final rejection point} - \text{initial content or content of new oil}}$$

*Chemist, U. S. Naval Engineering Experiment Station, Annapolis, Md. Paper on "The Work Factor of Lubricating Oil" presented at Annual Meeting, Am. Soc. Mech. Eng., December, 1930.

The average work factor is obtained by assembling the above data as follows:

Work value, viscosity at 100°F.	....
Work value, viscosity at 130°F.	....
Work value, viscosity at 210°F.	....
(A) Viscosity work value = $\frac{\text{total of above work values}}{3}$	
(B) Neutralization number, work value	....
(C) Carbon Residue, work value	....
TOTAL A, B and C	....
Average work factor of oil = $\frac{\text{total of work values}}{3}$	

The highest work factor possible for an oil is 1.00. Where any of the above work values is less than zero, a zero rating is given. An oil having an average work factor less than 0.60 is not considered suitable for use, nor is any oil which, when subjected to the test, exceeds any of the rejection points adopted in this connection. "A work factor equal to 95 percent of the registered work factor will be considered satisfactory on check test, i.e., if the official work factor is 0.7500, a work factor of 0.7125 on check test will be considered satisfactory, provided that none of the rejection points have been exceeded."†

Much has been written of late‡ both in explanation and discussion of this method of evaluating or expressing lubricating ability. In consequence, discussion of the machine will be limited to the accompanying illustration and its descriptive caption. (See Fig. No. 5.)

In realization of the importance of actual service tests as a check and as a means of developing further information, which is to date not practicable in the handling of certain of the above mentioned types of laboratory testing equipment, the Navy Department, after they have subjected oils to observation on the Work Factor Machine and the other usual laboratory tests for physical characteristics, generally run a service test on such oils.

†Bureau of Engineering, Navy Dept., Pamphlet N. Eng. 31, 1932 ed., "General Information for Refiners of Petroleum, Regarding Tests on Lubricating Oils." pp. 13-15.

‡National Petroleum News, June 11, 1930; Amer. Soc. Mech. Eng. Annual Meeting, 1930; Journal, Am. Soc. Naval Eng., November, 1929.

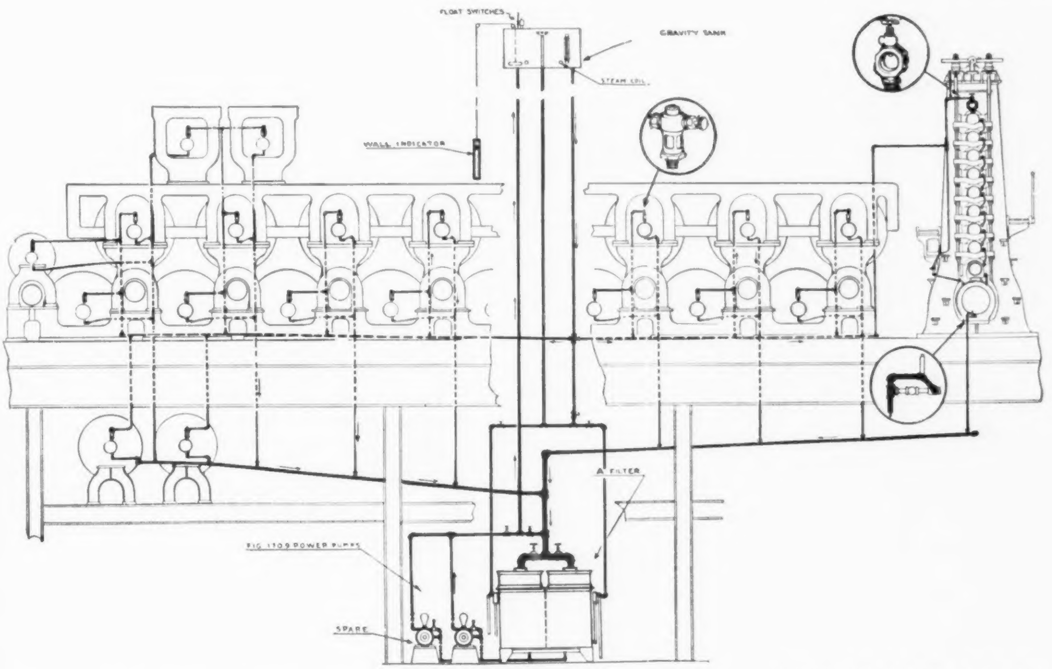
Paper Mills Calender Stacks

The purpose of the calender stack in paper mill operations is to impart a high finish or glaze to certain grades of paper after the sheet leaves the dryer end of the paper machine. The stack comprises a number of horizontal rolls, as shown in the accompanying illustrations. The treatment to which the paper is subjected is virtually an ironing process. In this treatment the sheet is exposed to high pressure, at a speed commensurate with the nature of the desired finish. Normally the higher the finish the greater will be the pressure and the higher the surface speed of the rolls.

The average stack carries from seven to eleven rolls. The size of these elements will vary according to the size of the mill. In general, however, the top and bottom rolls will be the largest, the intermediate being of somewhat less diameter, and consequently not so heavy.

Very heavy duty is involved, and both pressure and speed must be considered in any study of lubrication. In consequence the bearings of the average calender stack will often present a decided problem of lubrication. While this has been realized for a long time, it is only comparatively recently that concerted study has been given to developing a satisfactory solution, in the form of circulating flood oiling as a means of providing both lubrication and cooling. Continuous lubrication, however, has been practiced for a considerable period of time. It is brought about by delivering oil to the bearing of the top-most roll, the drainage from this element passing to the next below, and so on down to the bottom. Because of the lack of pressure on the oil supply, however, as well as the usual limited amount which can pass through the bearings, there may often be but little actual protection of lubrication. In other words, entry of contaminating dust to any extent would tend to accumulate in the bearing oil grooves rather than be washed out. Development of such obstructions to any marked degree could naturally be expected to impede the flow of oil, frequently, as experience has proved, to the serious detriment of the bearings, due to insufficient lubrication.

Study of circulating systems of lubrication, however, has indicated that the flood of lubricant developed by leading oil under sufficient pressure and in adequate volume to each re-



Courtesy of S. F. Bowser & Co., Inc.

Fig. 6. Showing manner of applying automatic flood lubrication to paper mill dryer and calender bearings. Here a continuous oil circulating system is applied to both parts of the machine. It is oftentimes preferable, however, to lubricate the dryer and calender bearings independently, according to the conditions in the plant. Flood lubrication, under sufficient volume and pressure, is particularly advantageous for there may be possibility of contaminating foreign matter within bearing oilways or other parts of the lubricating system.

spective bearing will effectively protect them from accumulation of non-lubricating matter by virtually washing this latter out during circulation of the oil. To insure that the oil will be of sufficient purity for continuous usage proper means of filtration must be installed with such a system, to remove any foreign matter as may be carried out by the return oil. The manner in which the filtering element can be located in a calender stack lubricating system is shown in Figure 6.

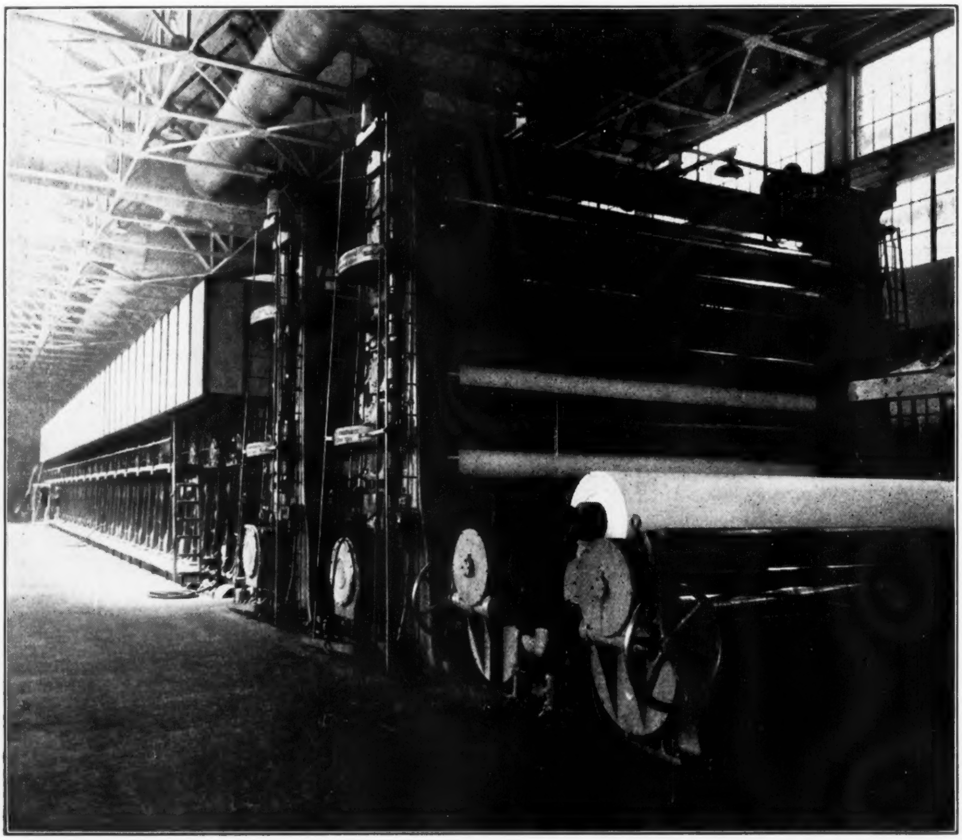
Lubrication an Adjunct to Cooling

Flood lubrication, whereby an excess of oil is constantly being circulated through bearing clearances, also affords considerable cooling. This is frequently very advantageous. While steam heated rolls are not used throughout the entire calender, the pressures of operation and crowding frequently develop considerable temperature. To an extent this will be conducted to the bearings, or in low clearance elements actually generated therein. By serving them with a flood of oil, however, lubrication as well as cooling is brought about, the return oil carrying away a considerable amount of heat, which is subsequently dissipated in the filter and storage tanks, prior to recirculation of the oil.

Bearing Design

Calender stack bearings may be of either anti-friction or plain sleeve type. Prevailing practice in the adaptation of anti-friction bearings to this type of service makes provision for an oil reservoir as a part of each bearing housing, with adequate means for checking the oil level.

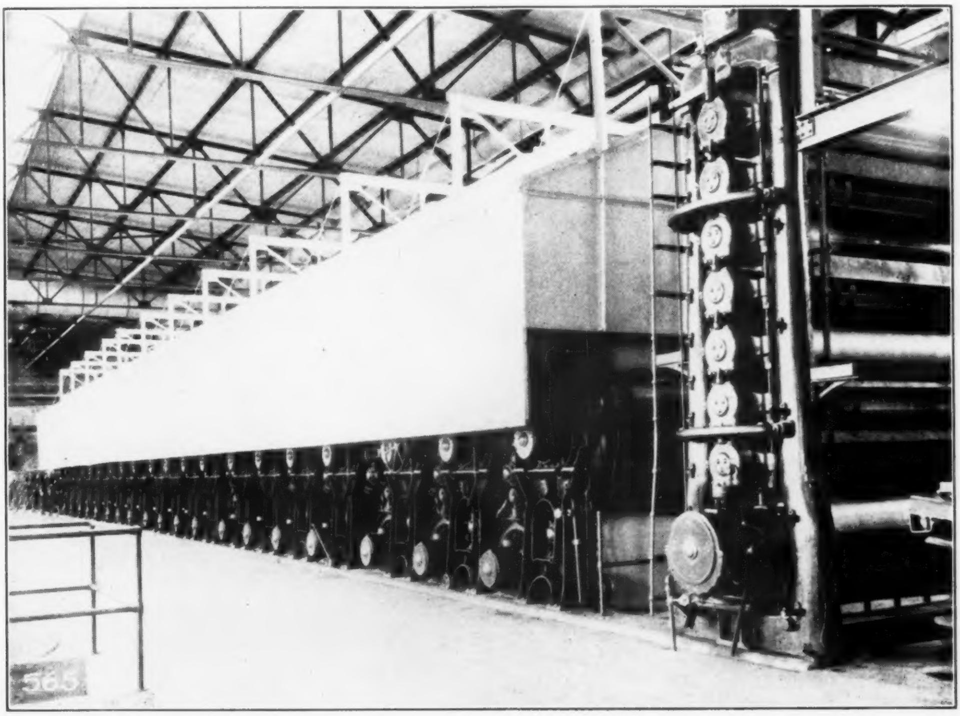
Where plain or sleeve type bearings are used, to sustain the heavy pressures which will so often be encountered, circulating pressure lubrication is normally preferred by the designers of the newer types of machines. In the opinion of certain authorities the oil overflow should be planned to take place at such a point in each bearing housing as to always leave a certain amount of oil in a suitable reservoir, which will insure reserve lubrication for a reasonable length of time, in the event of interruption or failure of the oiling system.



Courtesy of Farrel-Birmingham Co., Inc.

Fig. 7—Showing one of the most modern types of paper mill calender installations. Piping elements for the lubricating system can be seen adjacent to the calender frame.

Bearing design, of course, must always be studied with the view of preventing water, color or lint from the paper, (which may so often be blown by air on to the rolls) from gaining entry to the bearings, or otherwise capacity of the bearing reservoirs and the automatic action of the rings or collars in maintaining oil circulation will insure dependable and continued operation for a considerable period of time.



Courtesy of Beloit Iron Works.

Fig. 8—Showing close-up of a calender and location with respect to the dryer end of the paper machine.

contaminating the oil supply. For this reason, very careful thought has been given to providing each bearing with a suitable seal, to prevent entry of non-lubricating foreign matter. The use of any such seal, along with other means for preventing contamination of the oil, will, of course, apply to both plain bearings as well as anti-friction bearings.

To increase the benefits pertinent to circulating flood lubrication, ring or collar oilers are also adapted to modern calender bearings. The use of the ring or collar oiler in conjunction with an automatic oil circulating system is particularly noteworthy, for circulation if properly accomplished will insure against overheating, the flood of oil acting as a cooling or heat removing medium. Furthermore, means of filtration and cooling are frequently installed with such systems to give the further advantage of clean cool oil. There is also a decided element of dependability involved, for in case there should be any interruption of oil flow due to breakdown of the circulating system, or should it have to be cut out temporarily for minor repair or adjustment, the

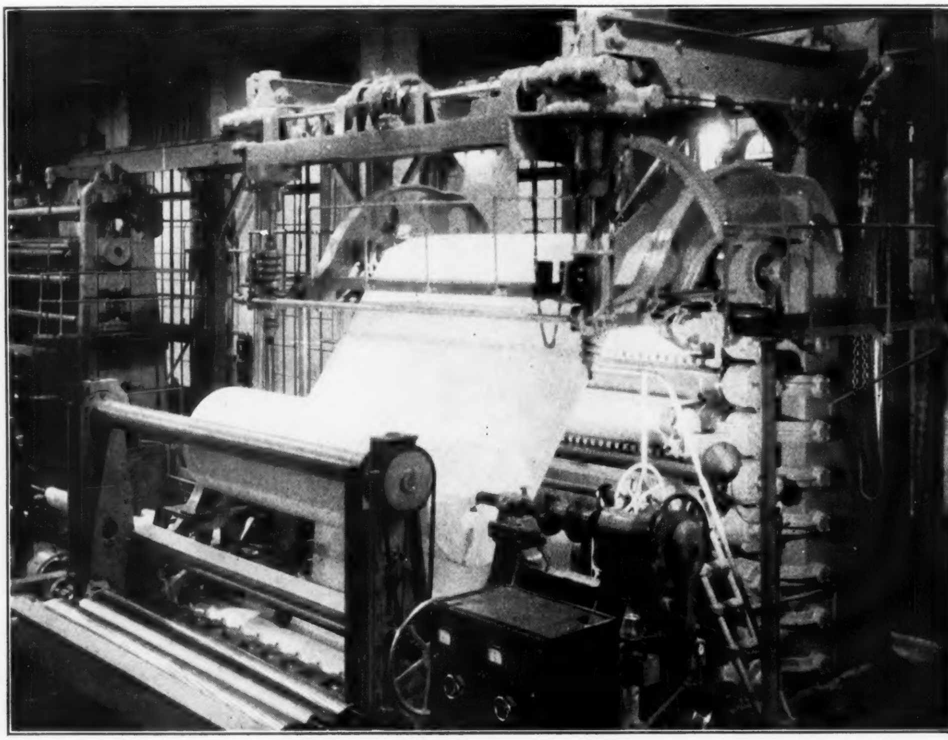
Bottom Roll Bearings

In the construction of calender roll bearings, experience has indicated that careful attention must be given to the bottom roll. Here clearance is very important; obviously, it must never be too great, otherwise there would be a possibility of appreciable reduction of the contact area to result in an increase in unit operating pressure. This has also been the reason for careful study of oil grooving of such bearings.

As an adjunct to design, the manner of applying lubricants to these bottom roll bearings is also important. In the opinion of certain authorities a direct lead from the oil distribution main to each of such bearings will insure the continuous delivery of cool, fresh oil, and a more effective counteraction of the cumulative pressure exerted by the entire set of rolls which comprise the stack. On the other hand, the oil outlet must be of ample size to carry off the oil discharge and relieve the bearing of any possibility of back pressure or crowding. This can be helped by carrying the oil grooves to the point of discharge in the bearing proper.

Effect of Manner of Drive

A recent survey of lubrication practice in British paper making mills, as compared with American practice, has developed some interesting and useful information, particularly to those who are concerned with manufacture and operation of calender stacks. Methods of drive have been given especially careful study, with a view to ascertaining relative advantages of driving through the second roll instead of the bottom roll, as is customary in American mills.



Courtesy of Beloit Iron Works.

Fig. 9—One of the latest types of super calender and winder installations showing open side arrangement. Practical lubrication of this type of machine has been materially simplified.

Advantages of the Second Roll Drive

From a lubrication point of view this has resulted in considerably improved bearing conditions; it is also claimed to have introduced other features of great importance to the paper maker, viz.:

The power required to drive the stack is reduced.

Heavy stacks equipped with plain babbitt bearings can be started up without the necessity of lifting the upper rolls.

The finish of the sheet is said to be considerably improved, due to greater slippage, particularly between the bottom and second rolls.

Slippage as developed with bottom roll drives is said to occur higher up the stack than when second roll drive is practiced. It is claimed that this latter gives greater slippage at the last roll passage in finishing the sheet. In other words, instead of starting the finish at the top of the stack in a more or less gradual manner, the glaze is imparted more instantaneously by the bottom rolls as the sheet leaves the stack. This is regarded as being conducive to a more uniform and greatly improved finish. Furthermore, if improved finish is not desired, second roll driving is claimed to give the same finish with much less pressure on the top roll.

Lubrication has been found to be materially facilitated in mills where the stack is driven through the second roll, for the bearings of the bottom roll have then only to carry the weight of the stack, with less resultant unit pressure. This means that drive stresses are carried by bearings that have to carry but little weight. It has also been found that pressure on the top roll bearing can be reduced, to somewhat overcome the usual difficulties which develop in the imposing of this pressure upon the cap of the bearing. But most important of all, it has been found that the necessity for special lubrication at starting, in the interest of reducing starting torque, can be eliminated.

Printed in U. S. A. by
Edgar C. Ruwe Co., Inc.
72 Washington St., N. Y. C.